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This special report was written for USAF vision specialists to use as a guide when prescribing spectacles for military aviators and to extend to the civilian sector the knowledge gained from the USAF experience. Visual correction in flyers presents some unique problems, especially for presbyopes. The demands of each individual aircraft environment need to be well understood. Ophthalmologists and optometrists must consider all pertinent aeromedical factors before prescribing spectacles for ametropic aviators.

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Prescribing Spectacles for Aviators: USAF Experience

ROBERT E. MILLER, II, O.D., M.S., JOHN F. KENT, O.D.,
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MILLER RE II, KENT JF, GREEN RP JR. *Prescribing spectacles for aviators: USAF experience.* Aviat. Space Environ. Med. 1992; 63: 80-5.

This special report was written for USAF vision specialists to use as a guide when prescribing spectacles for military aviators and to extend to the civilian sector the knowledge gained from the USAF experience. Visual correction in aviators presents some unique problems, especially for presbyopes. The demands of each individual aircraft environment need to be well understood. Ophthalmologists and optometrists must consider all pertinent aeromedical factors before prescribing spectacles for ametropic aviators.

A POPULAR SAYING in World War II (WW II) was "A pilot's eyes are his finest weapon!" Even today, in this age of radar, infrared imaging systems, head-up displays, and electronic warfare, a pilot's eyes are still "his or her finest weapon." Thus, prescribing appropriate spectacles is critically important for ametropic aircrew members.

The correction of vision in aviators presents unique problems, especially for aviators who are presbyopic. Although some problems may arise when prescribing a single-vision correction for distance acuity (e.g., binocular imbalance, overcorrection of myopia or astigmatism, etc.), there are a myriad of potential problems in prescribing bifocals for aviators. These include problems with distance refractive error, amplitude of accommodation, eye position of gaze in the cockpit, sitting height and aircraft seat position, and ambient illumination. United States Air Force (USAF) ophthalmologists and optometrists must consider these many factors when assessing the unique operational needs of each aviator for distant and near visual corrections. This re-

view provides background information for USAF ophthalmologists and optometrists about the visual needs of aviators, and discusses pertinent aeromedical factors. A comprehensive guide to cockpit instrument panel distances and print sizes for most USAF aircraft was recently published in USAFSAM-SR-89-5 (1).

Background

A 1988 study of USAF aircrew by the Ophthalmology Branch, Clinical Sciences Division, USAF School of Aerospace Medicine (2), found that 27.4% of pilots, 51.5% of navigators and weapons systems operators (Nav/WSO), and 40.2% of other aircrew members were required to wear spectacles when flying (Table I). These fliers are faced with, and many have reported, problems with wearing eyeglasses in an often hostile and dangerous environment. The problems include, but are not limited to, reduced field of view, fogging and perspiration on the lenses, nasal bridge discomfort, reflections at night, excessive weight, decentration from G-forces and/or vibrations, and hot spots underneath the helmet.

Furthermore, many USAF pilots are faced with the visual problems of presbyopia, the loss of ocular accommodative ability that occurs in middle age. A recent Air Force study reported that 16.5% of USAF pilots and 7.1% of Nav/WSOs are 40 years of age or older (3). The distribution curve of aviator ages showed a significant second peak around age 40 (Fig. 1). Other data from that study revealed that, of those who wear spectacles, 12.4% of pilots, 2.4% of Nav/WSOs, and 3.8% of other aircrew were required to wear bifocals when flying. These numbers actually underestimate the magnitude of this population, because they do not include the senior rated officers in nonflying staff or administrative positions. Also, many of the Air National Guard and Air Force Reserve fliers are bifocal wearers because their average age is 7 years older than those in the active force.

It is important to assure the presbyopic aviator that presbyopia is not a pathologic condition. While it is not usually a problem for most individuals until they reach

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AVIATOR SPECTACLES—MILLER ET AL.

TABLE I. AIRCREW MEMBERS REQUIRING SPECTACLES.

| Major Command | Pilots | Navigators and Weapon Systems Operators | Others |
|------------------|--------|---|--------|
| ATC ¹ | 25.8% | 51.1% | 56.2% |
| MAC ² | 25.9% | 49.2% | 36.1% |
| SAC ³ | 29.2% | 51.3% | 41.0% |
| TAC ⁴ | 30.2% | 54.8% | 53.9% |
| Total | 27.4% | 51.5% | 40.2% |
| N* | 3226 | 1634 | 1596 |

¹ Air Training Command; ² Military Airlift Command; ³ Strategic Air Command; ⁴ Tactical Air Command.

* N = Total number of aircrew members surveyed.

their mid-forties, some latent hyperopes may have problems much earlier. Because of strict entry vision standards for aircrew training, most USAF pilots do not wear spectacles before the age of presbyopia. However, this, in itself, causes problems when they must adjust to wearing spectacles in late middle age.

Asthenopia, or eyestrain, from near work may be the earliest symptom of presbyopia. In fliers, however, eyestrain may manifest itself as difficulty in seeing the flight instruments or flight charts under dim illumination. Red cockpit lighting at night will cause more eyestrain difficulties for the prepresbyope than blue or white lights. Red light is more difficult to see because it requires more accommodative effort due to the chromatic aberration of the eye (4).

USAF ophthalmologists and optometrists should consider the particular cockpit environment and the unique needs of each aviator when prescribing spectacles. The need for a prescription that provides sharp distance visual acuity in the military aviator is obvious. If distance visual acuity is found to be decreased (i.e., worse than 20/20), spectacles should be ordered and required for flying. On the other hand, the need to prescribe correction for near vision is not as apparent. The Armed Forces Vision Test Apparatus-Near/Distance (VTA-ND) is set for a 13-in near testing distance, and the Armed Forces Near Point Card is calibrated for 14 in. Testing at these distances is helpful in identifying those individuals requiring a spectacle correction for desk work, but these distances do not necessarily correlate with reading flight instruments or performing other cockpit tasks. The viewing distances for most USAF

aircraft instrument panels are 26–28 in (2). However, viewing distances may be even longer in some transport aircraft, depending upon the pilot's sitting height and arm length.

It is inappropriate to base near vision standards for flying exclusively on the findings of the VTA-ND or, for that matter, on instrument panel distances. Thus, a presbyopic flier's visual needs may or may not require near vision correction and must be assessed on an individual basis. Many early presbyopic aviators need only carry in their flight suits a pair of spectacles with the bifocal set for desk reading, in case they need them for a specific visual task during night flying. With advancing age, however, this will cease to be an option.

It may be necessary for the ophthalmologist or optometrist to visit the aviator on the flight line and personally evaluate the cockpit environment. Also, measurements taken with the flier wearing issued (not borrowed) life-support equipment may be needed to determine the appropriate bifocal add and segment height. The flight surgeon is always available to help the ophthalmologist or optometrist develop the appropriate aeromedical insight.

Professional judgment, based on prudent aeromedical knowledge, should be the most important factor in prescribing or not prescribing corrective lenses for the aviator. Incorrectly prescribed spectacles can lead to anxiety and frustration in flight or when training in flight simulators (5). USAF ophthalmologists and optometrists play an important role in prescribing spectacles; they must ensure that visual corrections for aircrew members are operationally appropriate.

Prescribing Single-Vision Spectacles

Most ametropic fliers will need only single-vision spectacles. During the evaluation, a detailed history should be obtained from the flier, including the type of aircraft and crew position. An accurate refraction is essential to maximize visual efficiency, but the vision specialist should be careful not to overcorrect the patient. If prepresbyopic aircrew members are overcorrected for their myopia, they may have difficulty at near reading distances, especially at night. Maps and many other flight publications have very small print. Overcorrecting hyperopia will provide good near vision, but will blur the flier's far vision, with resulting dissatisfaction. Inserting the final prescription in a trial frame and testing both far and near vision, as well as measuring near operational working distances, are ways to avoid error.

Two pairs of clear, single-vision spectacles and two pairs of N-15, single-vision sunglasses should normally be ordered. Rated crewmembers qualified to fly, but not actively flying, are authorized one pair of clear spectacles. An extra set of clear spectacles is ordered, when required, for gas mask inserts. Lenses with antireflective coatings are also available and may be prescribed when reflections or ghost images create a problem for the spectacle-wearing flier; e.g., during night flying. Whether aviators wear spectacles or contact lenses, it is mandatory, per Air Force Regulation (AFR) 60-16, paragraph 6-3 (3 March 1989), that they carry in their flight suits a spare set of current aircrew spectacles. In case of trouble with spectacles or contact lenses, fliers

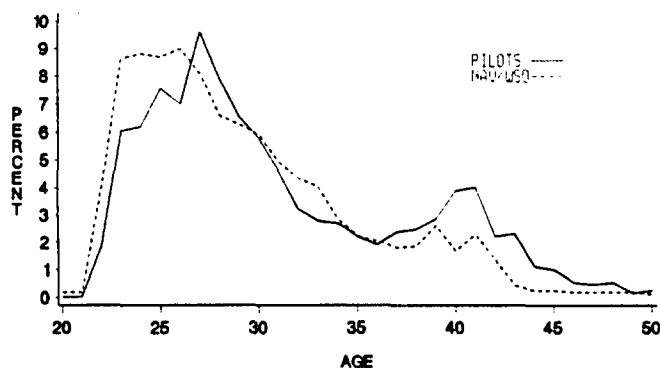


Fig. 1. Frequency distribution by age of USAF pilots and navigator/weapon systems operators (from USAFSAM-SR-89-5).

must be able to remove the problem eyewear immediately and use their spare spectacles. A 1989 survey (Miller RE II, presented to the USAF Aircrew Spectacle Working Group, Brooks AFB, Texas, Jan 90) revealed that 20% of spectacle-wearing USAF aircrew members have had a lens fall out of their spectacle frame during a flight; therefore, this requirement should not be taken lightly.

One of the most overlooked factors in prescribing single-vision aircrew spectacles is frame adjustment. Fliers should bring their helmets, oxygen masks, and headphones to the eye clinic for the dispensing visit, so that *all* spectacles may be properly adjusted with the flight gear in place. Having to perform frame adjustments on a spare pair of spectacles while flying is definitely not a good idea!

Prescribing Multi-Vision Spectacles

Good clinical judgment, along with a working knowledge of the aviator's environment, is essential in order to properly prescribe multifocal spectacles for aviators. It is important to determine the aircraft type, crew position, size of print, and working distances at which the flier is required to see. Specific questions should also be asked regarding the flier's ability to perform nearpoint cockpit tasks, especially at night. Near visual acuity demands and working distances vary for each aircraft and flight crew position. For example, in the F-4 Phantom II, the pilot's front instrument panel is approximately 32 in from the pilot's eyes, while the working distance from the navigator's instrument panel is approximately 20 in. Because of the F-16's 30° reclining seat, a pilot who wears bifocals will likely require a much lower bifocal segment than an F-15 pilot who sits in a more erect position. A presbyopic aviator who flies multiple aircraft may require a different set of spectacles for each aircraft.

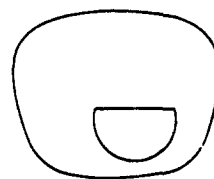
Slightly presbyopic fliers may require bifocal correction for a working distance of 14–18 in (desk work), and yet not normally require a bifocal correction for flying due to the farther working distance. However, they should be fitted for bifocal flying spectacles (2 clear, 2 sunglass) and carry a set of clear bifocal spectacles in their flight suits to be available should they be needed. A lower segment position may be useful for those prepresbyopic fliers who usually wear only distance spectacles, or none at all, so that the spare pair of bifocal spectacles would be a visually acceptable backup. Prescribing a full-strength bifocal to be used for desk work and a weaker bifocal to be used while flying is also a realistic option.

The USAF Cockpit Vision Guide (1) is a good source for approximating cockpit working distances and the letter sizes of cockpit instruments. The initial bifocal add should be inserted into a trial frame and evaluated at the cockpit working distance to determine whether it provides acceptable near vision. The spectacle prescription should also be evaluated under both normal illumination and dim illumination. The dim illumination should simulate the lighting condition in the cockpit during night missions.

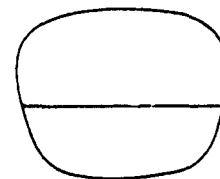
Various multifocal segment types and sizes are available (Fig. 2); for details, consult AFR 167-3 (1 January

MULTIFOCAL LENSES

BIFOCAL LENSES

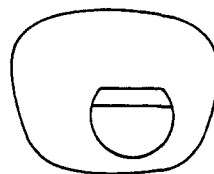


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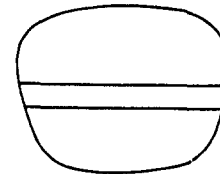


EXECUTIVE

TRIFOCAL LENSES

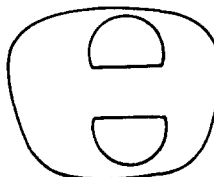


ST-7X25

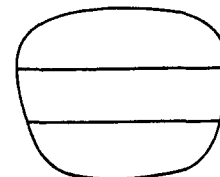


EXECUTIVE TRIFOCALS

DOUBLE SEGMENT LENSES



"DOUBLE D"



DOUBLE EXECUTIVE

Fig. 2. Multifocal lenses available for USAF aircrew personnel.

1986). Although progressive addition lenses (varifocal or invisible bifocals) have met with some acceptance in the civilian flying community, they are not currently authorized for USAF flight crews. The ST-25 is usually the bifocal lens of choice, especially in fighter or attack aircraft. The main advantage of the ST-25 over the Executive bifocal is that the ST-25 allows for distant peripheral vision around the bifocal segment. This additional peripheral vision is helpful during air combat maneuvering and in the landing flare. Navigators or weapons system operators and other aircrew members in tanker, transport, or bomber aircraft may find that the wider reading area of the Executive bifocal is useful, if they need to monitor wide instrument arrays or read large navigation charts. The vision specialist should work closely with the flier, explaining the advantages and disadvantages of each type of bifocal, in order to best satisfy each individual.

We recommend adjusting the bifocal segment height so that the top of the segment falls just above the highest instrument on the aircraft's instrument panel and below the glare shield. Some fliers may request that the bifocal height be set slightly higher or lower than this recommended height. Oxygen masks and helmets will affect the fit of the frame; in particular, the mask may cause the bifocals to sit higher than normal. It is essential that presbyopic fliers bring their helmets and oxygen masks on both the initial and dispensing visits to obtain the

proper bifocal segment height and the proper fitting of the frame. The adjustable nose pads on the flight frame provide a range of adjustment to maintain the proper bifocal height. On occasion, vision specialists may need to perform final bifocal fitting adjustments while the fliers are sitting at their crew positions in the aircraft.

By enlisting the aviator's help, the vision specialist can eliminate some of the uncertainty in determining proper bifocal height. An aircrew spectacle frame with plano sphere lenses can be fitted and loaned to the flier as a template. Then, in the aircraft, with the seat adjusted normally and helmet and oxygen mask being worn, the flier can mark on the template lenses with a black marker the location where the glare shield begins as shown in Fig. 3. The vision specialist can use the markings to accurately determine the proper operational bifocal height. This method of marking was first described by Harper and Kidera (6); it may be especially helpful for F-15 and F-16 pilots (Fig. 4).

Trifocals are available in the ST-7X25 and Executive styles, but standard trifocals have limited usefulness in the cockpit because of the small area devoted to the intermediate segment. Although the intermediate segment is what the trifocal wearer normally employs for general cockpit work, the height of this segment is too narrow to view the complete instrument panel without moving the head. As with bifocals, the vision specialist must consider the unique needs of the aviator when prescribing trifocals.

The Double-D and, to a lesser extent, the Double-Executive multifocal lenses are excellent prescriptions for presbyopic fliers such as Nav/WSOs, flight engineers, and boom operators who must read overhead

panels at relatively close distances (Fig. 5). The Double-D segment has a vertical separation of 13 mm between the top and bottom reading segments. The reading segments may be ordered with any combination of power. The Double-Executive lens has a vertical separation of 14 mm, and the top segment has a power that is two-thirds of the power in the bottom segment. Because of the capability of specifying any power for the top and bottom segments to meet the aircrew member's needs, the Double-D segment is probably the lens of choice.

Two pairs of clear and two pairs of N-15 multi-vision spectacles are ordered for and dispensed to any actively flying aviator requiring such correction. Rated crewmembers who must be qualified to fly, but are not actively flying, are authorized one pair of clear spectacles. Finally, special spectacles; e.g., night-vision goggle (NVG) safety eyeglasses, are available per AFR 160-43, paragraph 9-13 (29 April 1988), for aircrew members required to wear NVGs. Other unique spectacles include laser protective lenses and MAG-1 (mask-adaptable goggle) combat spectacles for chemical defense.

Adjustment Period

Whenever fliers are given new spectacle prescriptions, they should be informed about the possible problems that may be encountered while adjusting to the new spectacles. They should be warned about possible visual distortions that may make the visual scene appear to slant up, down, or to one side. Objects may appear larger or smaller than they really are. With a minor

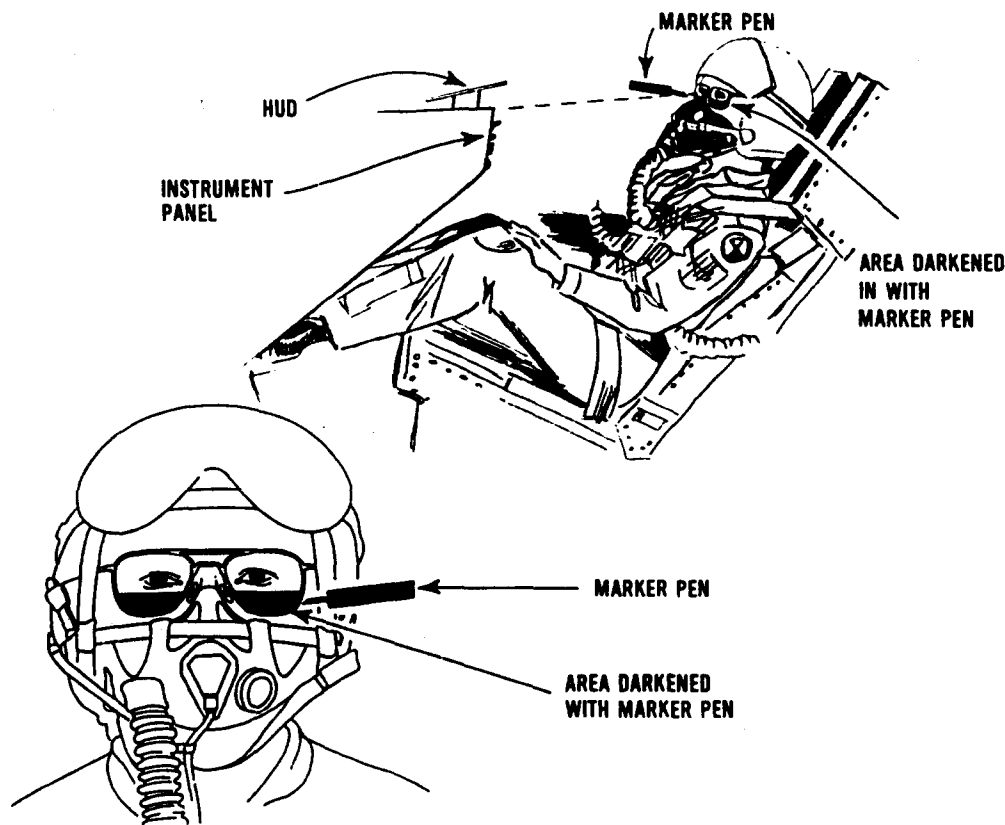
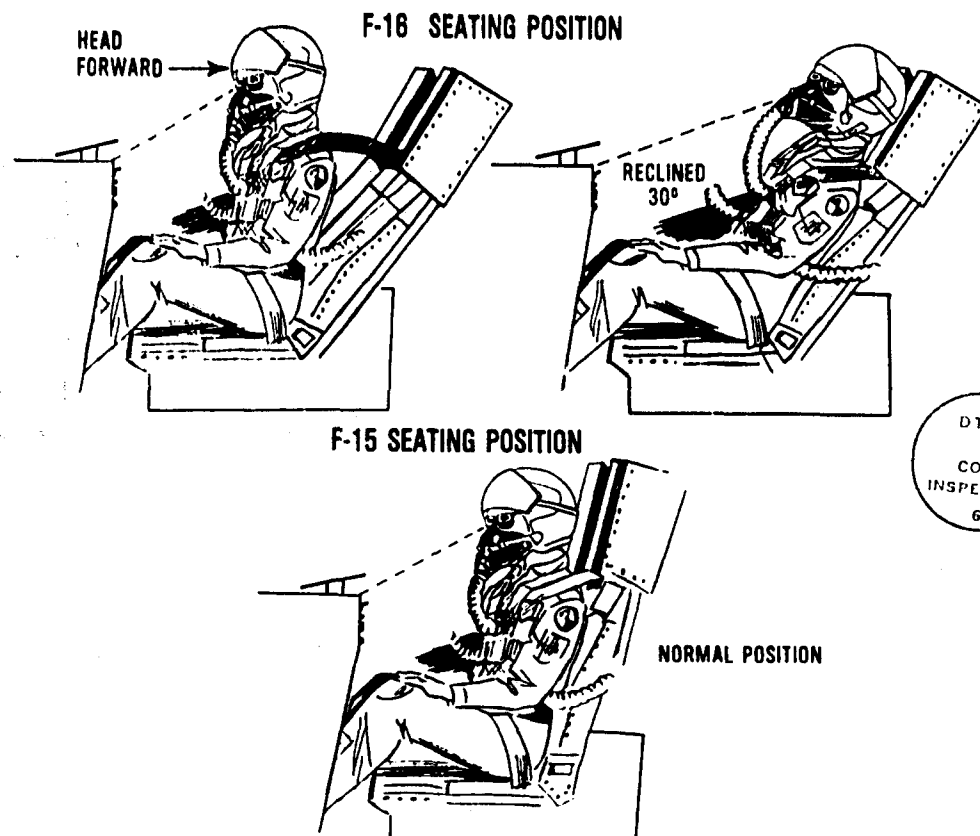


Fig. 3. Marker pen method to determine proper operational bifocal segment height.



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Fig. 4. Appropriate bifocal segment positions for F-15 and F-16 aircraft.

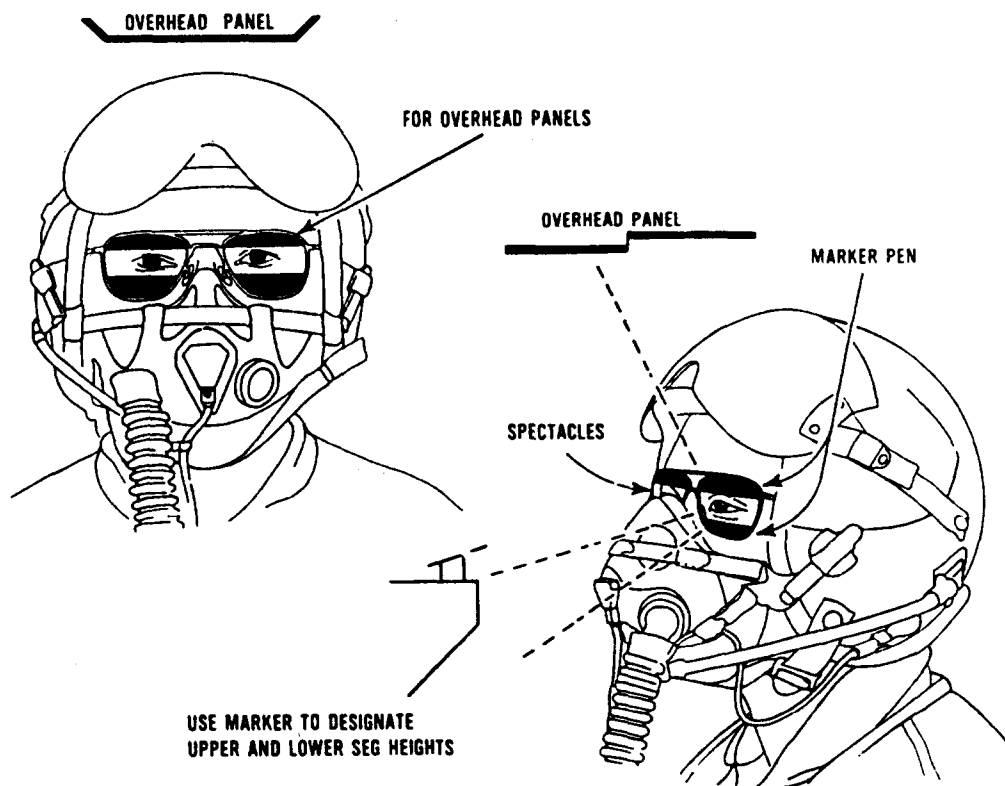


Fig. 5. Method of marking upper and lower segments for double bifocals.

change in prescription or a lens parameter, visual distortions may be present for a few minutes or hours, or not at all. With a significant change of prescription or lens parameter, the adaptation period may last for several days. To adjust to these new perceptual clues while

safely on the ground, first-time bifocal wearers should be told to practice scanning techniques while wearing their bifocals in a simulator or in the cockpit of a parked aircraft. This would also be an ideal opportunity to ensure that the spectacles fit properly.

AVIATOR SPECTACLES—MILLER ET AL.

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